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Commodity price return effects on GDP growth in inflationary times: empirical evidence from net-commodity-exporting countries

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Commodity price return effects on GDP growth in inflationary times: empirical evidence from net-commodity-exporting countries

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Abstract: This paper investigates the effect of real commodity price returns on the gross domestic product (GDP) growth rate, mainly in periods of inflation. The goal is to help policymakers and investors hedge this effect in net-commodity-exporting countries. We conduct our study with four commodity price indexes: energy, food and beverages, precious metals and agricultural raw materials. The panel smooth transition regression (PSTR) model is used to test the non-linear effect on GDP growth of real commodity price returns through the transitional channel of the inflation rate. We find a significant non-linear relationship between real commodity price returns and GDP growth rate for the different panels being studied. The research contributes to the existing literature by providing evidence that the inflation rate is one of the most important transmission channels of commodity prices to real economic activity. Moreover, the empirical results highlight how the positive impact of commodity price returns on GDP growth is dampened in the second regime (i.e. above the threshold value). During rising and persistent inflation, investors should diversify their portfolio beyond the traditional stock and bond markets to reduce the risk of inflation.

Keywords: Inflation hedge, net-commodity-exporting countries, commodity prices, panel smooth transition regression model, GDP growth.

JEL classification: C33, E31, O47, Q02.

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1. Introduction

Commodity prices have spiked in the last 4 years because of disturbances in supply chains during the COVID-19 pandemic and the Russo-Ukrainian war. The prices of commodities such as energy, food and beverages, and precious metals reached their highest fluctuations since the end of the 1970s (Fig. 1).

Increasing commodity prices have impacted global growth and heightened inflation around the world (Igan et al., 2022; Sen et al., 2024), for exporters and importers. From a theoretical perspective, commodity price fluctuations affect economic growth through several transitional channels (Ranosz and Kowal, 2020).[3] The first is through manufacturing industrial production costs (see, for instance, Ferraro and Peretto, 2018). Higher commodity prices increase the cost of production inputs, causing lead firms to move towards other sectors with less expensive inputs, potentially impacting short-term economic growth. The second transitional channel is through terms of trade: net-commodity-exporting countries benefit from higher commodity prices. However, the real impact on short-term growth depends on who – firms, households or governments – benefits from these changes. The third channel of transition is the inflation rate. According to Igan et al. (2022), the increase of some commodity prices, such as oil, wheat and metals, raises firms' prices and creates a higher and more persistent inflation rate that can lower economic growth.

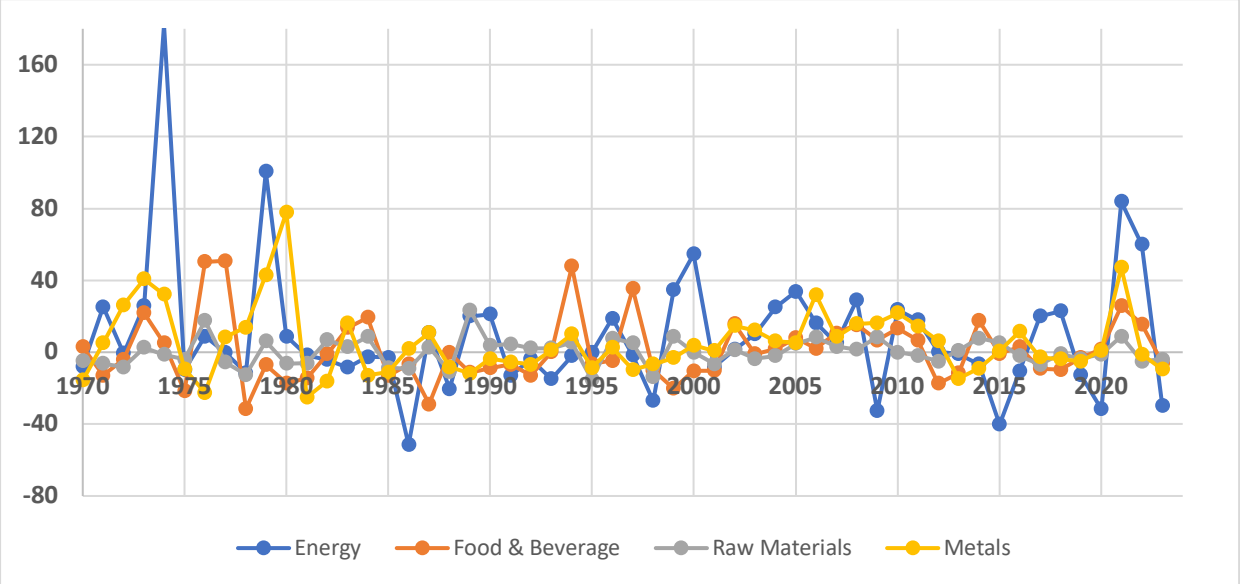

Fig. 1. Commodity price index year-over-year (1970 – 2023), source World Bank.

[3] According to Ranosz and Kowal (2020), some energy raw materials indirectly impact GDP for selected countries through transition channels such as production or inflation.

The recent inflationary pressures appear to be more impactful than those of the 1970s (see, for instance, Igan et al., 2022). A high inflation rate is often a feature of developing countries. But this time it is different, as investors in developed markets have not faced such a persistent rise in inflation for 40 years. Nonetheless, in some developed countries, particularly Europe and the US, inflation has fallen, falling below the 3% threshold for the first time this year (see, World Bank data). Core inflation, which excludes energy and food prices, also fell to 2.7% annually in Europe, but it remains high in developing countries.

Commodities show much higher real returns in periods of inflation than at other times: this should be investigated by looking at each commodity sector. According to Neville (2021), the best historical performance in inflationary periods was observed for commodities. The commodity markets show much higher real returns in periods of rising inflation. Nevertheless, higher commodity prices are likely to reduce growth and increase inflation in the short term. For instance, Hamilton (2011) highlighted that high energy prices have a negative effect on economic activity. Recent observations of the global economy demonstrate a significant economic slowdown and even weaker growth than expected for the 2024–25 period. For example, Germany, the main engine of the European economy, revised its growth rate downwards this year (2024). Therefore, certain central banks have revised their interest rates downwards to revive consumption and investment.

The existing literature has studied the importance of natural resources for net-commodity-exporting countries to achieve higher economic growth. When governments depend on natural resources, their revenue will fluctuate accordingly, complicating development planning. Indeed, resource revenue fluctuations can lead to inefficient spending of revenue and an uncertain investment environment that dampens investment and slows economic growth. Mohaddes and Raissi (2017) argue that fluctuations in the commodity terms of trade are associated with lower accumulation of physical capital, lower total factor productivity and, consequently, fewer possibilities for technological progress and weaker GDP growth. In this context, net-commodity-exporting countries face several issues maintaining a sustainable GDP growth rate under commodity price variations; and this may become more challenging during inflationary shocks.

The main goal of our paper is to investigate the effect of commodity price returns of energy, food and beverages, metals and agricultural raw materials on the real GDP growth rate in net-commodity-exporting countries. This study is innovative in that it measures the impact of

commodity prices on GDP growth through the transition channel of the inflation rate. Recent price increases have affected a broader set of commodities, and they have significant implications for output and inflation. Commodity price rises in the 1970s were concentrated in the oil markets. In recent years, however, the prices of energy, agricultural raw materials and metals have all increased significantly. Our objective, therefore, is to explain how to hedge this effect of commodity price returns and the role of investment strategies in periods of inflation. Our focus is to find key solutions for this time of inflationary crisis. The solutions could be found in, for example, financial development and economic diversification (Neville et al., 2021).

We assess the relationship between real commodity prices and real GDP growth using the non-linear PSTR model of González et al. (2005, 2017), and we introduce the inflation rate as a transitional variable. Several studies have empirically investigated this relationship using different methodologies and frameworks. According to Jimenez-Rodriguez and Sanchez (2005), the literature seems to have reached a consensus that the impact of some commodity prices (for example, oil) on macroeconomic variables may be asymmetric rather than linear. For instance, some studies have relied on the structural vector autoregression (VAR) model. Typically, they have found the effects of oil prices on economic growth to be small (Baumeister and Kilian, 2016a, among others). However, none of these approaches account for all of the transmission channels. Most of the techniques and models used do not perfectly explain the significance of the relationship between the commodity markets and real economic growth. Recently, new econometric tools have been used at a global level to explain the oil price decline in June 2014 by measuring the impact of oil price shocks on real economic cycles, as well as at a specific scale. Indeed, recent empirical results showed significant progress in terms of: (i) quantifying the asymmetry in the relationship between oil price volatilities and real economic activity in the US; and (ii) increasing recognition of the importance of non-linear models. However, many uncertainties remain in terms of modelling and the potential role of the transmission channels from the commodity markets to the real economy.

This study contributes to the existing literature in four ways. First, we focus on a range of net-commodity-exporting countries. The previous literature focused on the economic effect of commodity price volatilities in some developed countries, such as the US (Kilian and Vigfusson, 2013, among others) and Europe, as well as some low-income countries. This study is novel, contributing to the existing literature by analysing a panel of 41 net-

commodity exporters and covering price rises and inflationary times from 1970 to 2023. We contribute to the literature by answering the following question: Why is this inflationary period different? Second, this study analyses the impact on real GDP growth of four different commodity index categories: energy, food and beverages, metals and agricultural raw materials. By covering almost all commodity markets, it contributes to the literature by answering the following question: How does the impact differ between commodity groups? Third, we examine the indirect impact of commodity price fluctuations on economic growth through the transitional channel of the inflation rate using the PSTR model. Although many studies have evaluated the asymmetric effect of commodity price fluctuations on economic growth, we measure this asymmetry using a non-linear model in order to identify a new dynamic transition channel. This study goes beyond the existing results (such as Neville et al., 2021) and looks at how long the commodity market returns can stand in persistent inflationary times. It also asks which inflation rate threshold dampens the impact of higher commodity prices. Lastly, the threshold level of the inflation rate is determined by the PSTR model endogenously, according to the commodity category.[4]

The main findings of this study highlight a significant non-linear relationship between real commodity price returns and GDP growth rate for the different four panels under study. The relationship between the two variables seems to be different according to the inflation regimes. In the first regime, for the years when the inflation rate is under the threshold value, the commodity price returns positively impact the real GDP growth rate for all panels. In the second regime, for the periods when inflation is above the threshold value, the commodity price returns have a lower and negative impact on the GDP growth rate, except for the metals panel. It is clear, therefore, that the transitional variable linked to the inflation rate helps us to understand the dynamic relationship between commodity prices and real economic activity.

The remainder of this paper is organised as follows. Section 2 presents the existing literature. Section 3 explains the empirical model. Section 4 describes the data and some preliminary statistical analysis. Section 5 presents and discusses the main results and their robustness, and Section 6 concludes.

2. Literature review

For net-commodity-exporting countries, it is crucial to understand the economic effect of real commodity price fluctuations, especially for policymakers and investors. Several empirical

[4] In the study of Neville et al. (2021), the threshold level of the inflation rate is fixed statically at 5%.

studies have focused on analysing the effects of oil price fluctuations on the real economies of developed countries, particularly the US (Kilian and Vigfusson, 2011a; Herrera and Karaki, 2015, among others). Indeed, the drop in oil prices in mid-2014 revived the debate about the macroeconomic effects of oil price fluctuations in developed and developing countries (see, among others, Arezki and Blanchard, 2014; Baumeister and Kilian, 2016a, 2016b).

Most of the previous studies focused on energy commodities, especially the oil market. However, commodities such as food and beverages, raw materials and metals receive less attention in the literature, especially in terms of price fluctuations and their impacts on real GDP growth. Only a few papers have analysed the macroeconomic consequences of commodity price fluctuations. For instance, Cashin et al. (2004) investigated the long-term co-movement of real exchange rates and real commodity prices of 58 commodity-exporting countries. Recently, Torvik (2018) discussed why natural resources create prosperity in some countries and stagnation in others. Also, Mohaddes and Raissi (2017) highlighted that fluctuations in commodity terms of trade are associated with lower accumulation of physical capital, lower total factor productivity and, consequently, weaker economic growth.

In addition, the existing empirical studies have focused on the change in the relationship between commodity price fluctuations and GDP growth. Several studies (see among others, Jimenez-Rodriguez and Sanchez, 2005; Ibrahim and Chancharoenchai, 2014) confirm the intensity of the asymmetric response of economic output to commodity price shocks. Hamilton (2003) highlighted the asymmetric effects of negative and positive oil shocks. In this context, a non-linear approach allows the different steps of evolution – especially the change of level in the relationship over time – to be considered. This issue has been studied in several ways, including the nature of shocks, whether driven by demand or supply shocks, and the symmetrical or asymmetrical shape of its impact on the economy.

Kilian and Vigfusson (2011a) noted that several empirical studies support the hypothesis of asymmetric effects in the transmission of positive and negative oil price shocks to real economic growth. However, many of the studies quantifying these asymmetric responses are based on an empirical framework such as a VAR model or dynamic correlations that do not provide a valid and accurate answer to the central question of asymmetric effects. Indeed, many uncertainties remain in terms of modelling and the potential role of the transmission channels from the commodity market to the real economy.

According to Igan et al. (2022), fluctuating commodity prices affect macroeconomic conditions through several channels, with one being the inflation rate. For the authors, some

commodity prices, such as oil, wheat and metals, are related to consumption goods and production inputs. An increase in the prices of these commodities will erode economic growth. Abbas and Lan (2020) established a regime-varying methodology to capture the asymmetric response of inflation to the world of commodity prices. They found that the pass-through of commodity prices to inflation varies across inflation regimes. Meanwhile, Kyriazis et al. (2024) explored the dynamic interactions and connectedness between inflation, commodities and economic activity. The results highlighted significant insights into the determinants of the inflation rate, which constitute a receiver of impacts mainly from money supply, oil and gold.

More recent empirical studies have measured the spillover effects among the commodity market and inflation rate using a non-linear relationship (for instance, Diaz et al., 2023; Liu et al., 2023; Pan et al 2024). The main findings are that oil prices show a positive spillover effect on inflation and the commodity market, contributing to systemic risks and significantly impacting other economic variables. These recent studies extend the previous results, showing that commodity price fluctuations tend to pass through inflation rates (see also Benigno et al., 2022; Kilian and Zhou, 2022)

The existing results represent significant progress in the literature regarding commodity price fluctuation effects on economic activities. However, we found three key gaps. First, most of the investigations on co-movement and connectedness between commodity prices, inflation and macroeconomic variables focus on the oil and energy markets. There have not been enough studies on the different types of commodity or on comparing the energy, agriculture, and precious metal markets. Second, there is no evidence of the commodity price return effects on economic growth in the case of net-commodity-exporting countries. Indeed, most of the empirical studies have addressed the US economy or OECD countries and China. Third, many uncertainties remain in terms of modelling the asymmetric response of the inflation rate to commodity price fluctuations and its effect on real economic growth. Pan et al. (2024) assessed the dynamic relationship between US inflation and global commodity prices using the asymmetric Granger causality test. However, their study did not assess commodity price fluctuations on the real economy.

Given the significant non-linear relationship between commodity markets, inflation and macroeconomic variables, which varies across different time periods and market conditions, investors should adapt their investment decisions accordingly. Investors and policymakers should understand the dynamic long-term co-movement between the commodity market,

inflation and economic activity in order to implement an efficient strategy and policies to create more profit and real growth.

The main contribution of this paper is to test the role of inflation regimes as transmission channels in the relationship between real commodity price returns and real GDP growth rate. The commodity markets are more volatile than stock or equity markets. One could ask how these movements impact economic growth rate in inflationary times.

3. Empirical model

To examine the effect of real commodity price returns on GDP growth through a transitional channel, different methodologies have been developed. Some methods rely on the Granger causality test and cointegration relationship. In the existing literature, very few studies have asymmetric angles. For instance, Ferraro and Peretto (2018) proposed an endogenous growth model in which commodity prices affect short-term economic growth through transitional channels. According to Ranosz and Kowal (2020), some energy commodities have an indirect impact on GDP for selected countries through transition channels such as production or inflation. Moreover, Pan et al. (2024) stressed the importance of the asymmetric causality method in examining the relationship between global commodity prices and US inflation.

Accordingly, to study the effect of real commodity price returns on GDP growth through non-linear specification, we test Gonzales et al.'s PSTR model (2005, 2017). This model is useful for describing heterogeneous panels (as in the case of commodity-exporting countries) with regression coefficients that vary across individuals and over time. Heterogeneity is permitted by assuming that these coefficients are continuous functions of an observable variable through a bounded function of this variable, and they fluctuate between a limited number of "extreme regimes". Based on the PSTR model, the effect of real commodity price returns can vary depending on the transitional channel of the inflation rate. The change in the estimated value of coefficients is smooth and gradual, since the PSTR specifications are regime-switching models in which the transition from one state to the other is continuous rather than discrete.

The empirical model is defined as follows:

$$\Delta GDP_{i,t} = \alpha_i + \beta_0' X_{i,t} + \left[\beta_1' X_{i,t} * F\left(S_{i,t}; \gamma, c\right)\right] + \varepsilon_{i,t} \quad (1)$$

for $i = 1, \dots, N$ and $t = 1, \dots, T$, where N and T denote the cross-section and time dimensions of the panel, respectively. $\Delta GDP_{i,t}$ is real GDP growth. Furthermore, α_i denotes the country fixed effects and $X_{i,t}$ represents the matrix of explanatory variables, including the variations

of the real commodity price index and the main determinants of GDP growth, as evidenced in the literature.[5] These are the ratio of government expenditure to GDP, the ratio of gross fixed capital formation to GDP, the ratio of international trade to GDP, and the ratio of household consumption to GDP. F is a transition function, $S_{i,t}$ stands for the transition variable, defined here by the inflation rate, and $\varepsilon_{i,t}$ is an independent and identically distributed (i.i.d.) error term. The transition function $F(S_{i,t};\gamma,c)$ is a continuous function of $S_{i,t}$ and is normalised to be bounded between 0 and 1, and these extreme values are associated with regression coefficients β_0 and $\beta_0+\beta_1$. This transition function is given by:

$$F(S_{i,t};\gamma,c\,)=\left(1+exp\left(-\gamma\prod_{j=1}^{m}(S_{it}-c_j)\right)\right)^{-1} \quad (2)$$

with $\gamma>0$ and $c_1<c_2<\cdots<c_m$, γ is the slope parameter of the transition function and c_j $(j=1,2,\ldots,m)$ are the threshold parameters. According to González et al. (2005, 2017), it is usually sufficient to consider $m=1$ (logistic) and $m=2$ (logistic quadratic). In the case of $m=1$, the dynamic is asymmetric, and the two extreme regimes are associated with low and high values of the transition variable, where the change is centred around the threshold (c_1). In the case of $m=2$, the dynamic is symmetric, and the transition function has its minimum at $(c_1+c_2)/2$ and attains the value of 1 at both low and high values of the transition variable.

In our study the inflation rate plays the role of the transitional channel. Depending on the realisation of this variable, the effect of real commodity price returns on GDP growth is specified by the regression coefficients β_0 (in the first regime) and $\beta_0+\beta_1$ (in the second regime). This effect varies between commodity-exporting countries and time according to the value taken by the transition function, as follows:

$$\frac{\delta\Delta GDP_{i,t}}{\delta\Delta X_{i,t}}=\beta_0+\beta_1F(S_{i,t};\gamma,c\,)\qquad\forall m=(1,2) \quad (3)$$

When implementing the PSTR model proposed by González et al. (2005, 2017) three steps should be considered: first, model specification, which includes testing homogeneity against the PSTR alternative, and, if homogeneity is rejected, determining the appropriate form of the transition function (i.e. determining the value of m in equation (2)); second, estimating the PSTR parameters using the non-linear least squares methodology; and third, evaluating the PSTR estimators by conducting two misspecification tests of parameter constancy and of no remaining non-linearity.

[5] According to Espinoza (2012), these variables are all important determinants of economic growth in one form or another.

4. Data and preliminary analysis

This study examines the impact of real commodity prices on the GDP growth rate through the transitional channel of the inflation rate for four different country groups between 1970 and 2023. We consider four different commodity prices: energy, food and beverages, precious metals, and agricultural raw materials. Our data covers a large panel, including 41 net-commodity-exporting countries. The list of countries is given in Table A.1 (in the appendix), together with the main type of commodity exported by each one, and used to construct our panels (see Table A.2 in the appendix). The first important group is the energy panel, with 12 energy-exporting countries covering the main commodities: oil, gas and coal. The second important panel is food and beverages, in which seven countries export food and five export beverages. The two other panels are raw materials and precious metals, comprising nine and eight exporting countries, respectively. Two factors motivate the commodity countries selection procedure. First, we consider the main type of commodity exported by the country and its share of the total of country exports. Second, data availability is one of the main criteria of data selection. This is because our goal is to cover the long term to include the main inflationary times and to enable a solid comparison through time and across panels. Thus, we consider yearly data spanning 1970 to 2023, from the first oil shocks of the 1970s to the last commodity price increases in 2022–23.

Our data includes several other explanatory variables to control the impact of the model on GDP growth. The control variables are the ratio of government expenditure to GDP, the ratio of gross fixed capital formation to GDP, the ratio of international trade to GDP, and the ratio of household consumption to GDP. We use the real GDP growth rate, computed as the first log difference of a country's GDP and real commodity price index returns, to obtain elasticity coefficients in the same the level values of the control variables. The data for GDP and the other macroeconomic control variables are extracted from the World Bank database, and the Augmented Dickey-Fuller test of stationarity is applied for all variables. The test results indicate that all variables are stationary.[6]

As mentioned earlier, this study assesses the non-linear relationship between real commodity price returns and GDP growth, including the transitional variable represented by the inflation rate. The existing literature explains that inflation is very hard to define, and there is no single measure of the inflation rate. There are, in fact, various methods to compute inflation, such as the consumer price index (CPI) headline, CPI core, personal consumption expenditure

[6] The Dickey-Fuller test results are available upon request from the authors.

deflator, and the GDP deflator. We follow Neville et al. (2021), considering the CPI headline year-over-year as a measure of inflation. Investors in the real market believe this is the most appropriate measure, and a key advantage is that the data is available for a long period of time. The data on CPI is extracted from the World Bank database.

Table A.3 (in the appendix) reports the main descriptive statistics of macroeconomic variables. For the GDP growth rate, the four panels have almost the same mean, but the highest standard deviation is the energy panel, while the lowest is the agricultural raw materials panel. In other words, the energy countries group has the most heterogenous GDP growth rate, which may be explained by the dependency of these countries (such as Bahrain, Kuwait and Saudi Arabia) on commodity export revenue. For the inflation rate, the mean is high for all groups, between 9% for the energy panel and 16.4% for the metals one. This high inflation level is expected, as most of the countries in the four panels are developing countries that have historically suffered from price increases and fluctuations. For the other control variables, their features are normal and compatible with the situation of developing countries.

The data for real commodity price indices is extracted from the IMF Primary Commodity Prices database. As mentioned earlier, this study includes four different commodity indices: the energy price index (includes crude oil, natural gas and coal), the food and beverages price index, the metals price index (includes gold, silver and platinum) and the agricultural raw materials index (includes timber, cotton, natural rubber and tobacco).[7] Table 1 shows the summary statistics of commodity price index returns. We can see that the mean and standard deviation of energy price index returns is higher than for the other commodities. Since our data includes the oil shocks of the 1970s and the recent disturbance related to COVID-19, the high fluctuations of the energy price index seem logical, as the prices reached high and low spikes several times (for instance, +182% in 1974, and +51.5% in 1986). Moreover, the increasing financialisation of the energy commodities, especially the oil market, leave it more exposed to market co-movements and volatility, like other financial assets.

Table 1: Summary statistics of commodity price index fluctuations

	Energy	Food and Beverages	Metals	Raw Materials
Mean	9.31%	1.33%	5.29%	0.08%
Median	-0.29%	-1.04%	1.51%	-0.11%
StdDev.	36.49%	17.86%	18.78%	7.43%
Max	182.1%	50.89%	77.79%	23.42%
Min	-51.48%	-31.45%	-25.09%	-15.26%

Notes: StdDev for Standard deviation.

[7] The construction of these four indices is based on weights used in the World Bank Commodity Price Index. https://thedocs.worldbank.org/en/doc/5d903e848db1d1b83e0ec8f744e55570-0350012021/related/CMO-Historical-Data-Monthly.xlsx

5. Empirical results and discussion

In this study we evaluate the impact of real commodity prices on the GDP growth rate of net-commodity-exporting countries. We distinguish between four categories of commodity: energy, food and beverages, metals, and agricultural raw materials. The study also considers the pass-through of commodity prices to the inflation rate. In inflationary times, commodities have positive returns, but there is considerable variation within the commodity index (i.e. between different categories of commodity). Since there is a mitigating effect of commodity price returns, which may be compensated within the commodity complex or index, this study assesses this effect in a range of commodities and countries, with a long span.

5.1 Linearity test against PSTR specification

Before estimating any non-linear form, González et al. (2005, 2017) propose an initial specification test of the appropriate model, namely testing the linearity against the PSTR model. The PSTR is not identified if the data-generating process is linear, and a linearity test[8] is necessary to eliminate the estimation of unidentified models. To test the linearity hypothesis against the PSTR specification, we rely on the F-test. If the null hypothesis is rejected, the PSTR specification will be useful for describing heterogenous panels, with estimated coefficients that vary across regimes.

Table 2: Results of linearity tests against PSTR specification

	Energy		Food and Beverages		Metals		Raw Materials	
	$r = 0$	$r = 1$	$r = 0$	$r = 1$	$r = 0$	$r = 1$	$r = 0$	$r = 1$
F	3.415	2.864	8.362	1.522	1.972	0.706	13.662	2.376
	(0.000)	(0.015)	(0.000)	(0.181)	(0.011)	(0.645)	(0.000)	(0.038)

Notes: $r = 0$ refers to the null hypothesis of linearity against the alternative of a PSTR model with two regimes. $r = 1$ refers to the null hypothesis of PSTR model with two regimes against the alternative of a PSTR model with three regimes. F statistics for F-test. p-values are given in parentheses.

In this investigation the linearity is tested, considering the transition variable of the inflation rate. Thus, if linearity is rejected, the impact of commodity price returns on GDP growth is different across inflationary regimes, and depending on whether the inflation rate is high or low. The results of the linearity test are reported in Table 2. They highlight that the linearity hypothesis is rejected for the four panels. Therefore, the PSTR specification is most appropriate to assess the impact of commodity prices on GDP growth, and considering the non-linear relationship through inflationary regimes. The results in Table 2 also demonstrate the existence of a logistic transition function (i.e. *m=1*), that corresponds to an asymmetric relationship, including two regimes associated with low and high values of the transition

[8] Gonzalez et al. (2005, 2017) interpret the linearity test as a test of homogeneity.

variable. In the next section we estimate the PSTR model to assess the non-linear relationship between commodity price returns and real economic growth.

5.2 The impact of real commodity price returns on real GDP growth

The main contribution of this study, compared to the existing literature, is to highlight the extent of the impact on GDP growth of commodity price returns in periods of inflation. It also looks at the threshold that dampens the positive impact on real economic activity. Moreover, in this study the threshold value of inflationary regimes is estimated by the PSTR model, unlike the existing literature, where it has been fixed statistically at specific level (such as Neville et al., 2021).

Table 3 shows the results of the estimation of the PSTR model. The main findings demonstrate that the impact of commodity price returns on GDP growth is significant and asymmetric for the four panels being studied. The relationship between the dependent and independent variables appears to be non-linear, depending on the inflation regimes. The first regime corresponds to the time periods when the countries have a low inflation rate. Meanwhile, the second regime covers the periods when these countries have a high inflation rate (i.e. above the threshold value estimated by the PSTR model). Globally, the findings show different impacts within the two regimes depending on the threshold value of the transitional variable. In the first regime real commodity price returns have a significant and positive impact on GDP growth for the four panels. The impact becomes negative or decreases in the second regime, except for the metals panel, in which the estimate coefficient remains positive and increases. These findings align with the existing literature (see, for instance, Baumeister and Kilian, 2016a; Sen et al, 2024), which found that the real commodity prices seem to be an important determinant of economic growth, and the relationship follows a non-linear dynamic through a transitional channel of the inflation rate.[9]

Regarding the threshold value of the transitional variable (i.e. inflation rate), the estimation results show the highest level for the metals panel (around 19%), followed by food and beverages, raw materials (around 12% for both) and energy (approx. 5.9%). The high threshold value related to the inflation rate is expected, as most of the countries being studied are developing markets and historically characterised by high and persistent inflation (see descriptive statistics on inflation rate in Table A.3. in the appendix).

[9] See also Abbas and Lan, 2020; Igan et al., 2022; Pan et al., 2024.

Table 3: Estimation of the PSTR model

Estimation of equation (1): $\Delta GDP_{i,t} = \alpha_i + \beta_0' X_{i,t} + \left[\beta_1' X_{i,t} * F\left(S_{i,t}; \gamma, c\right)\right] + \varepsilon_{i,t}$

ΔGDP stands for real GDP growth rate (expressed in logarithm). $X_{i,t}$ represents the matrix of the real GDP growth determinants, namely, real commodity price fluctuations ($\Delta COMP$), the ratio of household consumption to GDP (*C/GDP*), the ratio of gross fixed capital formation to GDP (*I/GDP*), the ratio of government expenditure to GDP (*G/GDP*), and the ratio of international trade to GDP (*T/GDP*). $\hat{c}$ represents the estimated threshold value, and $\hat{\gamma}$ is the estimated slope parameter of the transition function.

	Energy		Food and Beverages		Metals		Raw Materials	
	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
$\Delta COMP$	0.0503***	0.0166*	0.0303***	-0.0138**	0.0265**	0.0535	0.0517*	-0.0605**
C/GDP	0.5734***	0.0375***	0.0365	-0.0667	0.1142**	-0.2026*	0.0835***	-0.0924
I/GDP	0.1281***	0.0291***	0.1434***	0.2165	0.1061**	0.3515**	0.0619	-0.1096***
G/GDP	0.6032	-0.2673	0.1610**	-0.1036	0.1688**	0.0982*	0.2244**	-0.3011
T/GDP	0.2717**	0.0372**	0.0109	-0.0201	0.0083	-0.0033	0.0118	0.0726***
$\hat{c}$	0.0588		0.1205		0.1914		0.1207	
$\hat{\gamma}$	325.1		376.8		1159.5		873.8	

Note: significant coefficient at 1% (***), 5% (**) or 10% (*).

A detailed analysis of the estimation results in Table 3 gives a deeper understanding of the main features and differences between the four panels. For the energy panel, the empirical results demonstrate that the variation in the real commodity price index has a significant impact on the GDP growth rate in both regimes. In the first regime the estimated coefficient is positive. Thus, an increase of 10% in the commodity price index will raise the yearly GDP growth rate by 0.5% for the years when a country has a low inflation rate (i.e. less than the threshold value of 5.9%). In the second regime, for the periods when the inflation rate is above the threshold value, the estimator is still positive but smaller and tending to zero. This finding contributes to the existing literature, highlighting that during high inflation regimes, commodity returns, such as in the energy sector, have a limited effect on GDP growth, and this effect is lower than the first regime (i.e. low inflation). According to Neville et al. (2021), many sectors, such as equities, firm profits and smaller companies, perform poorly during high and rising inflation; and the energy sector is only slightly better.

For the metals panel, we observe the same pattern in terms of the impact on GDP growth of real commodity price returns. Like in the energy panel, the impact is positive and significant in the first regime. However, in the second regime, the relationship between commodity price index and economic activity is not significant, even though the estimated coefficient is higher than in the first regime. Unlike the energy panel, the estimated threshold value ($\hat{c}$) is much higher (about 19%). This result is explained by the composition of the metals panel, which includes mainly developing countries from Latin America (such as Bolivia and Peru) and

countries from Africa (such as Zambia). These countries historically record high inflation rates (on average around 46% in Bolivia, 25% in Peru and 35% in Zambia).

Turning to the food and beverages panel, the results in Table 3 show that the estimated threshold value ($\hat{c}$) is twice as high as in the energy panel (around 12% and 5.9%). Two main factors may explain this. First, most of the countries in the panel energy are net oil and/or gas exporters, such as Bahrain, Oman, Saudi Arabia and the United Arab Emirates. These countries have pegged their currencies to the US dollar, which has a low and controlled inflation rate, even though there may be some episodic inflationary pressure. Second, 5 out of 12 countries in the food and beverages panel are in Latin America (such as Argentina, Colombia and Uruguay). These countries are characterised by a high and rising inflation rate in many periods, especially at the beginning of the 1990s. Considering our main estimator, the empirical results demonstrate that a rise of 10% in the real commodity price index will increase the GDP growth rate by +0.3%. This finding is similar to the previous one in the energy panel. However, in the second regime, the impact is completely different. Indeed, during the periods when the inflation rate is above the threshold value of 12%, the impact on GDP growth of the commodity price return tends to zero and even becomes slightly negative. According to Igan et al. (2022) an increase in the prices of some commodities will raise firms' prices, which they may pass onto consumers. Therefore, persistent inflationary periods could prompt a monetary policy response that lowers economic growth.

Let us now look at the last panel, agricultural raw materials, which has almost the same features as the food and beverages panel in terms of impact on GDP growth and threshold value (approx. 12%). In the first regime the real commodity price returns have a positive and significant impact on GDP growth rate. Indeed, an increase of +10% in commodity prices will raise the GDP growth rate by 0.52%. The asymmetric relationship is evident in this panel as the threshold value that splits the data into two groups, showing a clear contrast between the periods when the country's inflation rate is below 12% (regime 1) and when it is higher (regime 2). Consequently, in the second regime we see the negative impact of the commodity price index on GDP growth. As mentioned previously, in the case of the food and beverages panel, high and persistent inflationary pressures due to the increasing prices of some commodities will have the opposite effect on economic growth in some commodity-exporting countries.

Focusing now on the estimation results of the other determinants of GDP growth rate, almost all are highly significant, and they have a positive impact on real economic growth. As mentioned previously, the determinants include the ratio of household consumption to GDP

(*C/GDP*), gross fixed capital formation to GDP (*I/GDP*), government expenditure to GDP (*G/GDP*) and international trade to GDP (*T/GDP*). These are some of the most adopted control variables in the literature, as they are among the main determinants of the GDP growth rate (see, for instance, Espinoza, 2012). The empirical results in Table 3 demonstrate that the ratio of household consumption to GDP is a key determinant of GDP growth in the energy panel countries. The impact is highly significant and positive mainly in the first regime, even though it tends to decrease in the second regime but remains significant and positive. The impact of household consumption on GDP growth is also significant and positive in the case of the metals and raw materials panels, mainly in the first regime, when the inflation rate is less than the threshold value. However, the impact is less significant in the second regime for these two panels. In addition, the estimated coefficient is negative. The main explanation we can offer for this relates to the previous analysis on the negative impact of a high and persistent inflation rate. During these inflationary times, the increase in household consumption will raise firms' prices, which can lower real GDP growth. For the food and beverages panel, household consumption does not impact the GDP growth rate.

For the ratio of gross fixed capital formation to GDP, the impact on GDP growth is almost significant and positive for all panels, except in the second regime of the food and beverages panels, and in the first regime of the raw materials panel. During rising and persistent inflation, many sectors perform poorly, but investors might address their concerns about the inflationary risk by allocating more to alternatives to the traditional stock and bond markets (Neville et al., 2021).

Turning to the ratio of government expenditure to GDP, this is significant only in the first regime of the three panels of food and beverages, metals and raw materials. An increase of 10% of government expenditure raises the GDP growth rate by 1.6% in the food and beverages and metals panels, and by 2.2% in the raw materials panel. In the second regime the impact reduces and is not significant for most of the panels. This seems to corroborate with the previous interpretations of the high inflationary periods that could lower real economic growth, even when the government increases public spending.

For the last control variable, the ratio of international trade to GDP, the impact is only significant in the case of the energy panel. In the first regime, in the periods when inflation is less than 5.9%, an increase in international trade by 10% raises the GDP growth rate by 2.7%. This shows the importance of international trade based mainly on commodity exports for the energy countries. In the second regime, in the presence of a high inflation rate, the impact is significant but seems to be reduced and tending to zero.

To sum up, the empirical results revealed the existence of a significant non-linear relationship between real commodity price returns and GDP growth rate for the different panels being studied. In the first regime, for the years when the inflation rate is under the threshold value, the commodity price returns have a positive impact on the real GDP growth rate for all panels. These results are consistent with the literature (see, for instance, Baumeister and Kilian, 2016a; Mohaddes and Raissi, 2017; Sen et al, 2024,) which found that real commodity prices seem to be an important determinant of economic growth. In the second regime, for the periods when inflation is above the threshold value, the commodity price returns have a lower and more negative impact on the GDP growth rate, except for the metals panel. The relationship between the two variables seems to be different according to inflation regimes. It is evident that the transitional variable of inflation rate plays a key role in explaining the dynamic relationship between commodity prices and real economic growth. Our findings are consistent with the existing literature that supports the idea of asymmetric effects in the transmission of commodity price returns to GDP growth (see, among others, Elder and Serletis, 2010; Hamilton, 2011; Kilian and Vigfusson, 2013; Pan et al., 2024). Therefore, this study contributes to the existing literature by demonstrating that the inflation rate is one of the most important transmission channels of commodity price fluctuations to real economic activity. Moreover, the empirical results highlight how the positive impact of commodity price returns on GDP growth was dampened in the second regime, when the inflation rate was high and persistent (i.e. above the threshold).

5.3 Robustness test of the asymmetric effect

This section tests the robustness of our empirical results. Our findings evidenced the existence of an asymmetric effect of real commodity prices on GDP growth through the transitional channel of the inflation rate. The existing literature highlighted that commodity prices can affect macroeconomic variables through several channels. Igan et al. (2022) analysed several channels, such as inflation rate, production patterns, and terms of trade effects. This section therefore checks the robustness of the previous estimation results by considering a new transition channel related to the commodity terms of trade. Indeed, higher commodity price returns can boost the real income in net-commodity-exporting countries and may increase their GDP growth rate.

In the new specification of the PSTR model, we consider the change in the commodity terms of trade as the new transitional channel of the effect of commodity price returns to GDP growth. We can explain the choice of commodity terms of trade as an alternative for the

transitional channel by the importance of this variable for commodity producers and net exporters.[10] Several studies have highlighted that the commodity terms of trade are the key determinants of real economic activities (Cashin et al., 2004). Consequently, as the net-commodity-exporting countries mainly depend on the revenue from commodity exports, and given the large fluctuations in commodity prices, the commodity terms of trade may be a key determinant of GDP growth.

The empirical results reported in Table 4 confirm the previous findings. The new estimation of the PSTR model demonstrates the existence of a logistic transition function (i.e. *m=1*), which corresponds to an asymmetric relationship, including two regimes associated with low and high values of the commodity terms of trade changes. Indeed, commodity price returns have an asymmetric effect on the real GDP growth rate, according to the threshold value. Specifically, the effect is significant and positive in the first regime (i.e. low commodity terms of trade changes) for all panels, except for agricultural raw materials. However, in the second regime the effect on GDP growth of commodity price returns is only significant for energy and raw materials. The estimated value of the threshold varies between 1% (for metals) and 19% (for food and beverages). Turning to the control variables, as in the previous section, they globally help to explain GDP growth. Government expenditure and international trade seem to be the most important determinants of GDP growth.

Table 4: Estimation of the PSTR model through TOT transitional channel

Estimation of equation (1): $\Delta GDP_{i,t} = \alpha_i + \beta_0' X_{i,t} + \left[\beta_1' X_{i,t} * F\left(S_{i,t}; \gamma, c\right)\right] + \varepsilon_{i,t}$

ΔGDP stands for real GDP growth rate (expressed in logarithm). $X_{i,t}$ represents the matrix of the real GDP growth determinants, namely, real commodity price fluctuations ($\Delta COMP$), the ratio of household consumption to GDP (*C/GDP*), the ratio of gross fixed capital formation to GDP (*I/GDP*), the ratio of government expenditure to GDP (*G/GDP*), and the ratio of international trade to GDP (*T/GDP*). $\hat{c}$ represents the estimated threshold value, and $\hat{\gamma}$ is the estimated slope parameter of the transition function.

	Energy		Food and Beverages		Metals		Raw Materials	
	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
$\Delta COMP$	0.0492**	0.0026**	0.0187**	0.0544	0.0310**	0.0390	0.0379	0.1008**
C/GDP	0.0764	0.0245	0.0375	0.0962	0.1138**	0.1280	0.0902***	0.0741
I/GDP	0.0185**	0.0215***	0.1417***	0.0694	0.0205	0.1408*	0.0154	0.0607
G/GDP	0.2052	0.2157	0.1494**	0.7359***	0.2053**	0.3769*	0.1939***	0.1298
T/GDP	0.0836***	0.0457**	0.0124**	0.0638*	0.0278	0.0239	0.0184*	0.0345
$\hat{c}$	0.0735		0.1891		0.010		0.0554	
$\hat{\gamma}$	393.5		541.9		958.4		306.2	

Note: significant coefficient at 1% (***), 5% (**) or 10% (*).

[10] The choice of the terms of trade as a new transitional channel is also linked to data availability.

Several insights confirm that real commodity price returns and the GDP growth rate have a non-linear relationship. Indeed, both transitional channels tested in this study highlighted that the effect on GDP growth may differ according to the different regimes of inflation rate and commodity terms of trade changes. Globally, the robustness check confirms the asymmetric relationship between the real commodity price returns and the GDP growth rate in net-commodity-exporting countries; and this relationship can be transmitted through several channels (inflation, trade). However, our estimation results appear to show a clear behaviour when considering the inflation rate as the transition channel. For most panels, the effect was significant and positive in the first regime, when the inflation rate was low. On the other hand, the positive impact was dampened in the second regime, in times of high and persistent inflation. However, interpreting the estimation results using the commodity terms of trade is mixed. Higher commodity price returns have a significant and asymmetric impact on the real economy, but how GDP growth reacts depends on who profits from the higher income. The beneficiaries could be firms (through profits), households (through wages) or governments (through tax).

6. Conclusion and policy implications

The aim of this study was to assess the impact of commodity price index returns on the GDP growth rate through the transitional channel of the inflation rate. Previous studies of the macroeconomic effects of commodity markets have largely focused on oil price shocks and their impact on the US economy. Unlike the previous studies, this paper set out to assess the effect of various commodity price returns on the GDP growth rate in 41 net-commodity-exporting countries. We conducted our study with four commodity price indexes, including energy, food and beverages, precious metals and agricultural raw materials. The panel smooth transition regression model (PSTR) was used to test the non-linear effect on GDP growth of real commodity price returns through the transitional channel of the inflation rate.

The main findings were the existence of a significant non-linear relationship between real commodity price returns and the GDP growth rate for the different panels being studied. The relationship between the two variables seems to be different according to the inflation regimes. In the first regime, for the years when the inflation rate was under the threshold value, the commodity price returns had a positive impact on the real GDP growth rate for all panels. In the second regime, for the periods when the inflation rate was above the threshold value, the commodity price returns had a lower and negative impact on the GDP growth rate, except for the metals panel. We can see, therefore, that the transitional variable of inflation

rate plays a key role in explaining the dynamic relationship between commodity prices and the real economy. Our findings are consistent with the existing literature, supporting the idea of asymmetric effects in the transmission of commodity price returns to real economic growth.

Given the significant non-linear relationship between commodity markets, inflation and real economic growth, which varies across different time periods and market conditions, investors should adapt their investment decisions accordingly. Investors and policymakers should understand the dynamic relationship in order to implement efficient investment strategies and policies to create more profit and real growth. The solutions could be found in, for example, financial development and economic diversification (Neville et al., 2021). Moreover, investor could focus on the development of infrastructure and logistics to improve supply chain efficiency that can reduce the impact of commodity fluctuations on consumers and business. Additionally, monetary policy could be used by central banks as an efficient tool to stabilise inflation rates and reduce market uncertainty.

Appendix

Table A.1: List of countries

Country	Commodity type	Country	Commodity type
Algeria	Energy	**Nigeria**	Energy
Argentina	Food & Beverages	**Niger**	Metals
Australia	Energy	**Norway**	Energy
Bahrain	Energy	**Oman**	Energy
Bolivia	Metals	**Papua New Guinea**	Metals
Brazil	Metals	**Paraguay**	Food & Beverages
Canada	Raw Materials	**Peru**	Metals
Chile	Metals	**Philippines**	Food & Beverages
Colombia	Food & Beverages	**Saudi Arabia**	Energy
Honduras	Food & Beverages	**Senegal**	Raw Materials
India	Food & Beverages	**South Africa**	Metals
Indonesia	Energy	**Thailand**	Food & Beverages
Ivory Coast	Food & Beverages	**Togo**	Raw Materials
Kenya	Food & Beverages	**Tunisia**	Raw Materials
Kuwait	Energy	**Turkey**	Raw Materials
Malawi	Raw Materials	**Uganda**	Food & Beverages
Malaysia	Food & Beverages	**United Arab Emirates**	Energy
Mali	Raw Materials	**Uruguay**	Food & Beverages
Mexico	Energy	**Venezuela**	Energy
Morocco	Raw Materials	**Zambia**	Metals
Mozambique	Raw Materials		

Table A.2: Main commodity exports and share of primary commodities in total exports

	Principal exports			Share in commodity exports (in %)		
Country	1	2	3	1	2	3
Argentina	Soy Meal	Wheat	Maize	18	13	11
Australia	Coal	Gold	Aluminum	22	14	12
Bolivia	Zinc	Tin	Gold	27	18	13
Brazil	Iron	Coffee	Aluminum	21	15	10
Canada	Softwood Sawn	Aluminum	Wheat	28	14	12
Chile	Copper	Fish	Fishmeal	70	9	6
Colombia	Coffee	Coal	Bananas	48	19	18
Honduras	Coffee	Bananas	Shrimp	47	30	6
India	Rice	Shrimp	Soy Meal	18	15	12
Ivory Coast	Cocoa	Coffee	Cotton	65	14	6
Indonesia	Crude Petroleum	Natural Gas	Natural Rubber	34	23	7
Kenya	Tea	Coffee	Fish	53	30	5
Malawi	Tobacco	Tea	Sugar	78	8	7
Malaysia	Palm Oil	Natural Rubber	Hardwood Logs	44	15	15
Mali	Cotton	Gold		88	12	
Mexico	Crude Petroleum	Copper	Coffee	72	5	5
Morocco	Phosphate Rock	Fish	Lead	55	14	7
Mozambique	Cotton	Sugar	Maize	33	19	9
Niger	Uranium	Tobacco		96	3	
Norway	Crude Petroleum	Natural Gas	Fish	67	13	8
Papua New Guinea	Copper	Gold	Palm Oil	23	23	20
Paraguay	Soybeans	Cotton	Soy Meal	44	26	9
Philippines	Coconut Oil	Copper	Bananas	29	21	12
Peru	Copper	Fishmeal	Gold	28	19	15
Senegal	Phosphate Rock	Groundnut Oil	Fish	29	29	16
South Africa	Gold	Coal	Iron	46	20	5
Thailand	Rice	Natural Rubber	Shrimp	26	24	23
Togo	Phosphate Rock	Cotton	Coffee	44	40	9
Tunisia	Tobacco	Phosphate Rock	Shrimp	23	21	20
Turkey	Tobacco	Wheat	Sugar	34	16	14
Uganda	Coffee	Fish	Gold	71	8	4
Uruguay	Beef	Rice	Fish	36	27	13
Zambia	Copper	Sugar		97	2	

Notes: weights are calculated for the period 1991-2011. Source: Cashin et al. (2004), Table 1, pp. 246-247.

Table A.3: Descriptive statistics

	GDP_Growth	Inf	G/GDP	I/GDP	C/GDP	T/GDP
			Energy Panel			
Mean	3.61%	8.82%	18.26%	24.22%	64.53%	60.99%
Median	3.70%	5.52%	19.21%	23.02%	64.59%	60.48%
StDev	7.67%	11.08%	5.67%	12.28%	9.10%	22.62%
Max	82.80%	86.23%	31.19%	79.29%	82.86%	142.6%
Min	-41.01%	-3.20%	6.78%	1.89%	40.45%	16.36%
			Food and Beverages Panel			
Mean	4.16%	12.41%	12.22%	20.56%	78.33%	62.23%
Median	4.70%	7.41%	12.03%	19.66%	79.54%	51.04%
StDev	4.07%	15.29%	3.21%	6.70%	9.14%	42.43%
Max	22.17%	96.99%	22.16%	50.31%	99.1%	220.4%
Min	-10.89%	-7.63%	2.97%	8.09%	49.27%	7.66%
			Metals Panel			
Mean	3.14%	16.39%	14.21%	17.76%	81.44%	43.93%
Median	3.43%	7.04%	13.63%	17.09%	82.38%	45.45%
StDev	4.39%	22.64%	3.67%	5.09%	8.22%	15.28%
Max	13.96%	98.0%	21.97%	32.78%	99.16%	85.26%
Min	-17.05%	-7.79%	5.40%	7.92%	60.25%	14.39%
			Agricultural Raw Materials Panel			
Mean	3.75%	9.08%	15.64%	20.11%	80.54%	59.62%
Median	3.83%	3.89%	15.72%	19.37%	79.67%	56.84%
StDev	4.03%	16.45%	3.53%	4.70%	12.23%	19.22%
Max	20.28%	105.2%	24.44%	40.31%	83.61%	186.6%
Min	-15.09%	-6.24%	7.52%	8.88%	46.62%	9.09%

Notes: StDev is the Standard Deviation. GDP_Growth is the GDP growth rate (expressed in logarithm), inf is the inflation rate, G/GDP is the ratio of government expenditure to GDP, I/GDP is the ratio of gross fixed capital formation to GDP, C/GDP the ratio of household consumption to GDP, and T/GDP is the ratio of international trade to GDP.

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